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FOR

**INTEGRATED MONOPOLE REINFORCEMENT SLEEVE
SYSTEM AND METHOD**

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1 INTEGRATED MONOPOLE REINFORCEMENT SLEEVE SYSTEM AND METHOD

2

3 Background of the Invention4 (1) Field of the Invention

5 The present invention relates generally to reinforcement of monopoles and, more
6 particularly, to an integrated monopole sleeve system and method for reinforcement of
7 the monopole at select, predetermined locations.

8 (2) Description of the Prior Art

9 Monopoles are widely employed as supports for antennae and other devices for
10 wireless communication. They are also used to supports conductors in power
11 transmission. An increase in the use of wireless communication has led to an increased
12 demand for monopole capacity. Existing monopoles are thus being employed to elevate
13 increasing numbers of antennae and other devices for wireless communication, often
14 beyond the rated capacity of the monopoles. These monopoles are therefore prone to fail,
15 resulting in damage to the monopole and supported equipment and loss of service to the
16 users.

17 Self-support monopoles are tapered or stepped. Stepped monopoles are formed
18 by joining together monopoles of various diameters. Diameter and wall-thickness
19 increases as the distance from the apex increases to reduce the overall weight and
20 expense of the monopole and allow the self-supporting monopoles to act as cantilevers
21 when the loads travel to the ground in a bending mode. The maximum moment is always
22 at ground level. Therefore, the moment and strength of the monopole decrease towards
23 the apex. Further, monopoles are flexible structures that can undergo large deflection, at

1 the apex, of up to 10% of their height under maximum loads. Since monopoles normally
2 support appurtenances near the apex, the bending moment at any location along the
3 height is the vector sum of primary moment and secondary moment. The primary
4 moment at a specific location is due to wind load on the projected areas of the
5 appurtenances, pole, platforms, etc while the secondary moment is due to all weights
6 above that location as they deflect from the vertical position. The secondary moment is
7 usually very significant for tall monopoles due to the large top deflection. Since the
8 moment increases as the distance from the apex increases, any additional appurtenances
9 or devices, such as antennas, microwave dishes, mounting platforms or brackets,
10 transmission lines, lights, reflectors, signs, flags, and the like not accounted for in the
11 design of the structure may cause structural failures. Because the function of the
12 monopole is to elevate appurtenances above the ground, and therefore the majority of the
13 appurtenances are attached at or near the apex of the monopole, these present a greater
14 projected area at or near the apex of the monopole and thereby increasing the bending
15 stress or inertial moment in the area of least strength of the monopole. These devices
16 may add approximately between 500 to 4000 lbs weight to the monopole. This weight is
17 not excessive under low wind conditions because the weight is supported axially through
18 the centerline of the monopole. However, under higher wind conditions, these
19 appurtenances add to the secondary moment of the monopole. Therefore, as wind speed
20 increases, the bending stress increases in a disproportionately greater manner due to the
21 addition of the weight of the appurtenances to the bending stress of the monopole.

22 Monopoles were originally designed to house wave-guides or coaxial cables
23 internally, allowing them to exit through portholes at the apex of the monopole in

1 proximity of the antennas. However, monopoles so designed are now being employed to
2 support a number of wave guides beyond their internal capacity. These wave-guides
3 must therefore be attached externally to the monopole and thus require an external
4 support. Additionally, these external wave-guides increase the projected area of the
5 monopole.

6 Therefore, a need exists to support or reinforce the monopoles such that they can
7 support more appurtenances at or near the apex and not fail under adverse conditions,
8 such as high winds.

9 Several solutions to this need have been proposed, including splints, guy wires,
10 various types of sleeves, and other braces. Some of these prior art reinforcing supports
11 were initially developed for wooden poles or lattice tower structures, not for metallic or
12 composite monopoles elevating a plethora of devices. Therefore, they either support the
13 monopole inadequately or not at all. Other prior art reinforcing supports that may be
14 used as monopole supports were originally designed to be applied in close proximity of
15 the ground, utilizing ground insertion as additional support. They are designed more for
16 stabilizing the entire monopole relative to the ground than providing bending resistance at
17 elevated locations of the monopole. Thus, they are not optimally configured for
18 freestanding reinforcement of the monopole at higher elevations. Some prior art devices
19 require considerable time for installation, and are therefore not well suited for application
20 at elevated heights due to the inherent danger of working at these heights. Others require
21 highly skilled technicians to apply the support, resulting in an increased cost of
22 installation and/or improper installation.

1 Guy lines are also employed to provide reinforcement to monopoles. However,
2 these require a large area at the base of the monopole, create an obstacle for vehicles and
3 persons, and are not suitable for the attachment of appurtenances at elevation.

4 Some prior art devices can extend for a considerable length along the monopole,
5 but apply the bracing force to small areas of the monopole and to the device. These
6 devices subject the monopole and themselves to increased forces in small, focused area,
7 thus increasing the wear and fatigue of both the monopole and device in these areas.

8 Thus, there remains a need for a monopole reinforcing system that is easy to
9 install at any elevation on the monopole, can distribute the reinforcing forces uniformly
10 over the monopole circumference, and can provide support for appurtenances.

11 Summary of the Invention

12 The present invention is directed to an integrated monopole sleeve system and
13 method for reinforcement of the self-supporting monopole at select, predetermined
14 locations.

15 These and other aspects of the present invention will become apparent to those
16 skilled in the art after a reading of the following description of the preferred embodiment
17 when considered with the drawings.

18 Brief Description of the Drawings

19 Figure 1 is a cross-sectional end view of a reinforcing sleeve constructed according to the
20 present invention.

1 Figure 2 includes two more cross-sectional end views and a cross-sectional side view of a
2 reinforcing sleeve, and a side view of the end flange of the preferred embodiment
3 according to the present invention.

4 Detailed Description of the Preferred Embodiments

5 In the following description, like reference characters designate like or
6 corresponding parts throughout the several views. Also in the following description, it is
7 to be understood that such terms as "forward," "rearward," "front," "back," "right,"
8 "left," "upwardly," "downwardly," and the like are words of convenience and are not to
9 be construed as limiting terms.

10 Referring now to the drawings in general, the illustrations are for the purpose of
11 describing a preferred embodiment of the invention and are not intended to limit the
12 invention thereto. As seen in Figures 1 and 2, an integrated monopole reinforcement
13 sleeve system, generally referenced as 10, includes at least one pair of reinforcing
14 complementary hemi-sleeves 12 with flanges 14. The flanges 14 are of width 34 and
15 equipped with holes 15, through which bolts 17 or other fasteners can be inserted to join
16 the complementary hemi-sleeves. These bolts or fasteners are then tightened such that
17 the hemi-sleeves form a reinforcing sleeve around the monopole. The flanges may be
18 fitted with a reinforcing brace 19 in order to be able to apply more compressive force to
19 the sleeve assembly prior to the flanges deflecting. As best shown in Figure 1, the cross-
20 sectional shape 16 of the sleeve 12 approximates the shape of the monopole outer edge or
21 perimeter 18. This perimeter can be circular or multi-sided, such as polygonal-shaped,
22 for example hexagonal or octagonal. Figure 1 shows a cross-section of a preferred
23 embodiment according to the present invention designed to reinforce a monopole with a

1 circular shaped perimeter. The sleeve is installed at a predetermined location on the
2 monopole for optimal reinforcement of the structure. If necessary, multiple sleeves may
3 be installed on the monopole.

4 The sleeve is designed such that it fits snugly around the monopole. To enhance
5 the snugness of the fit and thereby increase the reinforcement of the monopole, a
6 compressible material 22 with non-slip or shear force transfer properties can be
7 positioned between the sleeve and the monopole. This material may also serve as a
8 gasket to prevent the rubbing of metal against metal, to reduce the roughness of the
9 monopole surface, and to ensure good distribution of loads between the existing
10 monopole and sleeve along the circumference of the pole. The sleeve is thus compressed
11 around this material and the monopole. The compressibility of the material allows the
12 reinforcing force of the sleeve to be distributed more uniformly across the surface of the
13 monopole. The non-slip properties of the snugging material prevent the sleeve from
14 slipping or shifting position. Monopoles and other elongated structures tend to have a
15 modulus of elasticity that allows them to deflect and vibrate under wind pressure.
16 Therefore, a compressible and non-slip material with elastic properties that acts as a
17 damper to dissipates energy and prevents the slippage between the sleeve and the
18 monopole may be disposed at selected locations between the sleeve and the monopole for
19 ensuring transfer of loads therebetween.

20 For example, neoprene may be used as the shear force transfer material.
21 However, other types of materials can be used, such as elastomers, polymers, foams, and
22 adhesives. In general, the sleeves do not need to be removed once installed. Therefore,
23 semi-permanent materials such as adhesives can be used. For example, a thick strip of a

1 resilient polymeric material having an adhesive coating could be mounted in an axial or
2 spiral fashion about the monopole to effect transfer of shear forces between the sleeve
3 and the monopole. Also, an expansive foam material, for example neoprene foam, could
4 be injected in the space between the sleeve and monopole.

5 Tightening the sleeve around the monopole will considerably increase the bending
6 resistance of the pole. The system is now composed of two concentric, adherent
7 cylinders, which are much stronger and thus better resist bending than one cylinder alone.

8 If the thickness of the monopole and sleeve are the same, then the monopole in
9 the area of the sleeve would have about twice the bending resistance of the monopole
10 alone. Since self-supporting monopoles are subjected to primary bending, then the total
11 bending resistance would approximate the sum of the bending resistance of the pipe and
12 sleeves.

13 When the two sleeves are properly installed and tightly hugging the monopole,
14 the monopole will have increased resistance to shear forces or transverse load because the
15 sleeve and monopole are in contact through the hard neoprene gasket.

16 Such a system for the distribution and absorption of force according to the
17 preferred embodiment is in contrast to other reinforcing systems in which the reinforcing
18 force is applied directly to small areas of the monopole, rather than the entire sleeve.
19 Thus, the system according to the preferred embodiment will supply reinforcing support
20 distributed over a large area under normal conditions, and also absorb shock forces over a
21 large area under extreme flexure conditions. These properties prevent a smaller area of
22 the monopole and sleeve from experiencing extreme force and wear, and thus the system

1 according to the preferred embodiment does not fail as readily as other reinforcing
2 systems and extends the functional life of the monopole.

3 In the preferred embodiment, neoprene is used as the shear force transfer material.
4 Neoprene is used because of its compressibility, elasticity, surface adherence, and
5 resistance to inclement weather, such as extreme temperatures and humidity. Other
6 materials with these properties may be used, such as synthetic polymers, foams, and
7 adhesives.

8 Thus, an integral sleeve including the reinforcing sleeve, snugging material, and
9 monopole is formed, as is shown in figure 2, which provides reinforcing support, stability
10 of position, and shock absorption. The sleeves can be used for a variety of types of
11 monopoles, including constant diameter poles, also known as stepped poles, tapered
12 poles, and the like.

13 Monopoles are frequently used as supports for appurtenances, such as antennas,
14 mounting platforms or brackets, transmission lines, ladders, lights, reflectors, signs, flags,
15 and the like. These appurtenances can be weighty and confer a larger project area to the
16 monopole, and therefore may locally overstress the monopole if attached without
17 additionally supporting the monopole. In such cases, a sleeve according to the preferred
18 embodiment can be fitted to the monopole at the location where the appurtenance is to be
19 mounted, and then the appurtenance is mounted to the reinforcing sleeve. Thus, the
20 reinforcing sleeve is appropriately constructed with mounting supports to which
21 appurtenances can be mounted. For example, in the preferred embodiment, the bolts used
22 to tighten the sleeves can be used as mounting supports for wave guides, ladders, or step
23 bolts.

1 These mounting supports can be of different shapes and methods, according to the
2 appurtenances to be mounted. The reinforcing sleeve can include an initial excess of
3 mounting supports at installation, such that additional appurtenances can be mounted to
4 the reinforcing sleeve later without necessitating the replacement of the reinforcing
5 sleeve. For example, the sleeves can be provided with middle flanges to mount
6 appurtenances. Alternately or additionally, the sleeves may be provided with end flanges
7 28 equipped with holes 29. In these cases, the dimensions of the holes on the sleeve end
8 flanges must match those on the existing flanges of the monopole and the holes on the
9 sleeve end flanges must be oversized or slotted to allow tightening the sleeves.
10 Additionally, to accommodate any openings in the existing pole, the sleeve should have
11 matching oversized openings, preferably about ½ inch wider, to allow for tightening the
12 sleeves. For example, step bolts that have been threaded into bolt-supports welded to the
13 monopole can be easily removed by unthreading them. However, the bolt supports
14 project out of the monopole surface and therefore the sleeve should have matching
15 oversized opening. Alternately, one can use a thicker neoprene gasket or mechanically
16 remove the projected bolt supports.

17 While it may be desirable to provide the sleeves with end flanges to be bolted to
18 the existing pole-flanges of stepped monopoles, they are not essential, particularly if the
19 end flanges make the installations difficult or risky. Removing the end flanges will
20 considerably simplify the detailing and installations of the sleeves. The sleeve would
21 then act in a similar manner to the plates used to reinforce angles in lattice towers where
22 the plates are stitch-bolted to the legs of the angles. The bond between the angle and the
23 reinforcing plates in the lattice towers is more critical because the loads traveling through

1 the angles are axial while the loads on monopoles are transmitted to the ground through
2 bending.

3 The location of the overstressed regions of the monopole can be determined by
4 calculation. The calculated cross-sectional area and moment of inertia of the monopoles,
5 sleeves, and reinforced monopoles for stepped-type monopoles according to a preferred
6 embodiment of the present invention shown in Figures 1 and 2 with diameters ranging
7 from 24 to 54 inches are displayed in Table 1. In the calculations shown in the attached
8 spreadsheet, the wall-thickness of the sleeves is assumed to be the same as those of the
9 existing monopole sections. To reduce the weight of the sleeves, a thinner wall-thickness
10 and higher steel grade such as grade 60 ksi instead of grade 45 ksi may be used. This may
11 results in lighter sleeves for ease of installation. The formulas used for the calculations
12 are as follows:

13 The sleeve cross-sectional area, A , as best shown in Fig. 2, is calculated as

14
15
$$A = A_S + A_F$$

16
17 Where A_S is the area of the sleeve and A_F is the area of the fins.

18
19
$$A_F = 4 t L$$

20
21 Where t (not shown) and L are the thickness and length of the fin, respectively.

22
23
$$dA_S = t r d\theta$$

24
25 Where r is the radius and θ is the angle shown in Fig. 1.

26
$$A_S = 2 \int_{\varphi}^{(\pi-\varphi)} t r d\theta = 2 t r (\pi - 2\varphi)$$

27
28 Where φ is the $\tan^{-1}(\text{gap}/2r)$, where the gap is the distance between the vertical fins of
29 the sleeves. The distance contributed by one sleeve is shown as $\frac{1}{2}$ gap in Fig. 1.

30
31 Integration leads to

32
33
$$A_S = 2 t r (\pi - 2\varphi)$$

1
2 Then, the area of the fins and sleeve is given by

3
4 $A = 4 t L + 2 t r (\pi - 2\varphi)$

5
6 The moment of Inertia, I , is calculated thus:

7
8 $I = I_S + I_F$

9
10 Where I_S is the moment of Inertia of the sleeve and I_F is the moment of Inertia of the fins,
11 respectively.

12
13 $I_F = 4 [L t^3/12 + L t (r \sin \varphi)^2]$

14
15 $dI_S = (r d\theta) t (r \sin \theta)^2$

16
17 $dI_S = r^3 t \sin^2 \theta d\theta$

18
19
20 $I_S = 2 \int_{\varphi}^{(\pi-\varphi)} t r^3 \sin^2 \theta d\theta$

21
22 Integration leads to

23
24 $I_S = t r^3 [\pi - 2 \varphi + \sin(\pi - 2\varphi)]$

25
26 Then, the moment of inertia of the fins and sleeve is given by:

27
28 $I = 4 [\frac{1}{12} L t^3 + L t (r \sin \varphi)^2] + t r^3 [\pi - 2 \varphi + \sin(\pi - 2\varphi)]$

29
30
31 Referring now to Table 1, an evaluation of the increase in moment of inertia

32 provided by the preferred embodiment indicates that a reinforcing system according to
33 the preferred embodiment which employs a sleeve of the same thickness as the monopole
34 would increase the moment of inertia over 100% along the weak axis of the sleeve, in
35 effect more than doubling the moment of inertia along the direction of the weak axis of
36 the sleeve. It should be noted that the increase in moment of inertia along the direction of
37 the strong axis of the sleeve will be greater than this calculated increase, and thus the

- 1 sleeves should be oriented to provide the maximum bending resistance against loads,
 2 such as appurtenances and/or prevailing winds.
- 3 Table 1. Moments of Inertia for Sleeve-reinforced Monopoles According to the Present
 4 Invention.

Existing Monopole							
Outside Diameter	in	24	30	36	42	48	54
Thickness	in	0.25	0.3125	0.375	0.375	0.375	0.375
Inside Diameter	in	23.5	29.375	35.25	41.25	47.25	53.25
Area	in ²	18.65321	29.14563	41.96971	49.0383	56.10688	63.17546
Moment of Inertia	in ⁴	1315.343	3211.285	6658.921	10621.58	15908.27	22709.85
Reinforcing Sleeve - Weak Axis ^{1,2}							
Neoprene thickness	in	0.25	0.25	0.25	0.25	0.25	0.25
Inside Diameter	in	24.5	30.5	36.5	42.5	48.5	54.5
Angle phi	(radians)	0.081724	0.065621	0.054822	0.047076	0.041249	0.036705
Sleeve thickness	in	0.25	0.3125	0.375	0.375	0.375	0.375
Area Sleeve	in ²	18.42728	28.98639	41.92617	48.99713	56.06748	63.13743
Area Fins ³	in ²	8	8	8	8	8	8
Total Area (Sl. + Fin)	in ²	26.42728	36.98639	49.92617	56.99713	64.06748	71.13743
Sleeve m. of Inertia	in ⁴	1488.076	3589.539	7383.408	11606.05	17192.48	24333.56
Flange m. of Inertia	in ⁴	8.166667	8.166667	8.166667	8.166667	8.166667	8.166667
Total m. of Inertia	in ⁴	1496.242	3597.706	7391.575	11614.21	17200.65	24341.73
Reinforced Pole							
Moment of Inertia	in ⁴	2811.585	6808.991	14050.5	22235.79	33108.92	47051.58
Increase reinforced pole inertia	%	113.7531	112.0332	111.0026	109.3454	108.1239	107.1858

- 5
- 6 1. Gap between reinforced sleeves = 2 inches.
- 7 2. Moment of Inertia is calculated around the weak axis.
- 8 3. Fin length = 4 inches; fin thickness = ½ inch.
- 9

10

11 As can be observed by the reader, a proper installation is necessary to maximize

12 the bending resistance conferred by the integral sleeve system. Therefore, an installation

13 procedure should be written and approved by an appropriately qualified engineer for the

14 safe and proper installation of the sleeves prior to the commencement of installation. A

15 typical installation procedure is as follows:

- 1 1. Calculate the stresses along the monopole length according to the applicable code,
2 such as the EIA/TIA latest revision for antenna structures or ASCE for Power line
3 structures;
- 4 2. Identify the locations of the monopole requiring reinforcement;
- 5 3. Design the sleeve required to reinforce the monopole consistent with these
6 calculations, including designing the thickness of the sleeve such that the maximum
7 utilization of the reinforced monopole does not exceeds 80%;
- 8 4. Remove projected items such as step bolts, ladder or antenna supports, or coax
9 cables;
- 10 5. Clean the surface of the monopole where the sleeves are to be installed;
- 11 6. Install the neoprene gasket and hold it in place using a temporary tie or robe;
- 12 7. Install the sleeves:
 - 13 7.1. If the sleeves have flanges for bolting to the existing flanges of a stepped
14 monopole section, remove only half the nuts and bolts of the monopole flanges,
15 including upper and lower flanges, to allow one part of the sleeve to be bolted to
16 the monopole flanges. After securing part 1 of the sleeve in place, remove the
17 other half of the nuts and bolts from the monopole upper and lower flange and
18 install the second half of the sleeve. Secure the sleeve to the monopole flanges.
19 In this case temporary guys above the section being reinforced should be used for
20 safety.
 - 21 7.2. If the sleeve has no flanges, then the two parts of the sleeve can be lifted and
22 secured in the appropriate location on the monopole.

1 7.3. Install the threaded bolts along the vertical fins and tighten the two parts of the
2 sleeves using two nuts. The oversized holes on the sleeve flanges, if used, should
3 ensure tight fit between the monopole and the sleeve.

4

5 It should be noted the preceding procedure must be discussed with the
6 construction foreman and may be modified to suit site condition and available
7 construction equipment.

8 Certain modifications and improvements will occur to those skilled in the art upon
9 a reading of the foregoing description. By way of example, different materials can be
10 used to form the sleeves, including non-metallic composites. All modifications and
11 improvements have been deleted herein for the sake of conciseness and readability but
12 are properly within the scope of the following claims.

13